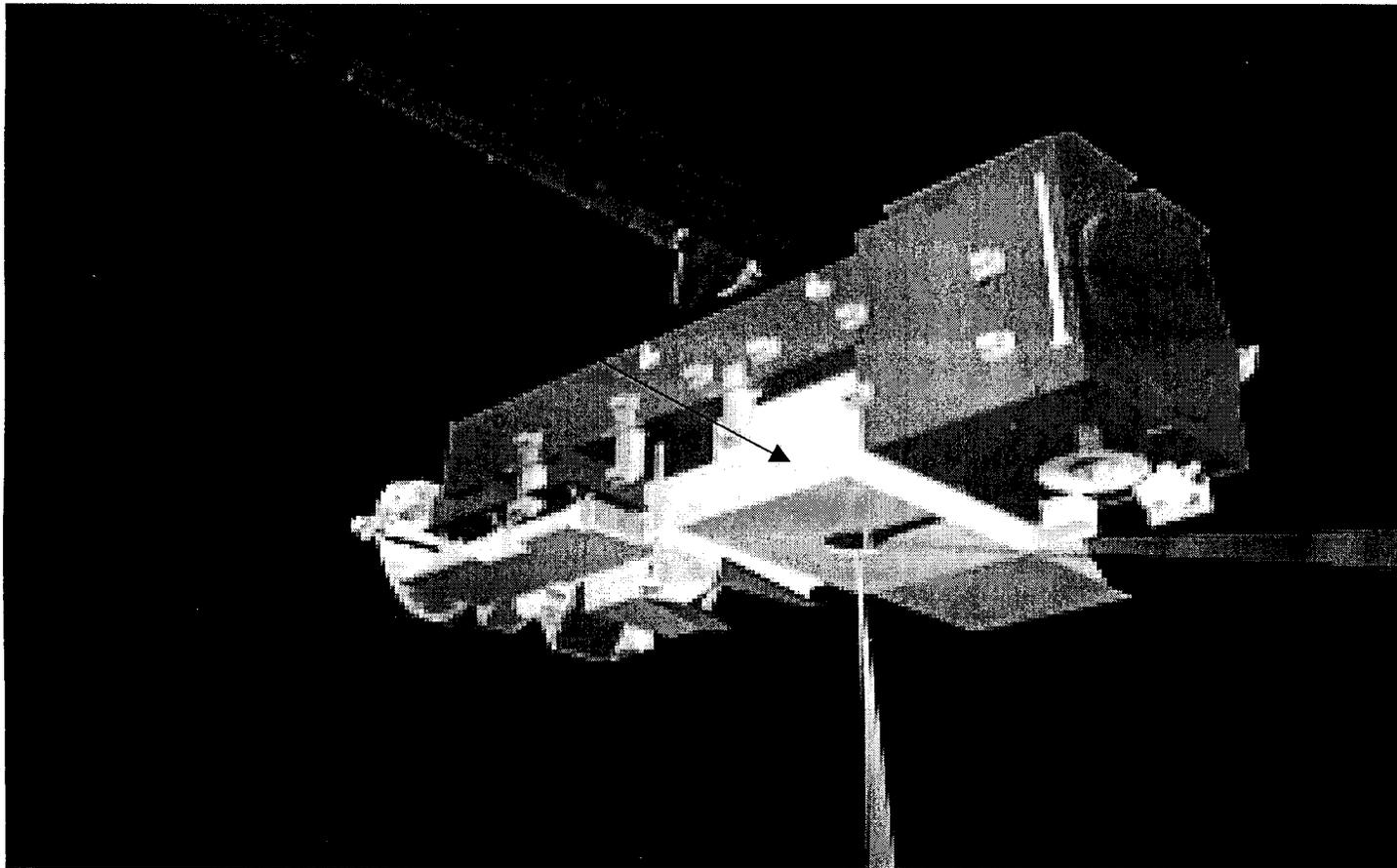


The EOS-CHEM Tropospheric Emission Spectrometer (TES)

A summary presentation of tropospheric chemistry issues and how TES measurements will contribute to their understanding



TES on the CHEM Platform

The TES Experiment

Global measurements of tropospheric ozone and its precursors from TES combined with *in-situ* data and model predictions will address the following key questions:

How is the increasing ozone abundance in the troposphere affecting

- *climate change?*
- *oxidizing reactions that “cleanse” the atmosphere?*
- *air quality on a global scale?*

Tropospheric Emission Spectrometer Formal Investigator Team

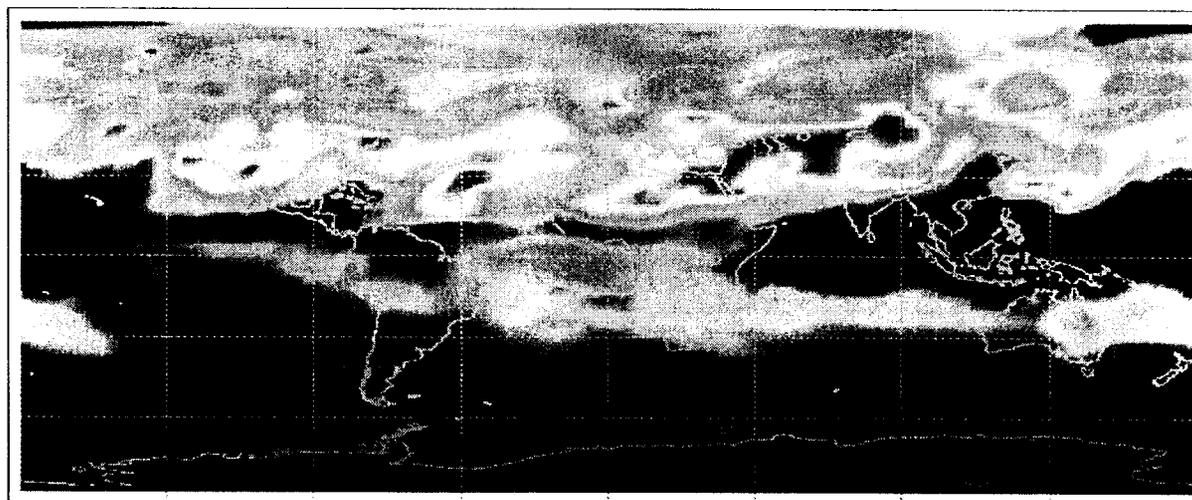
NAME	INSTITUTION	ROLE
Reinhard Beer	JPL	Principal Investigator
Shepard A. Clough	AER, Inc.	Retrieval Algorithms; Validation
Daniel J. Jacob	Harvard University	Tropospheric Chem. Modeling
Jennifer A. Logan	Harvard University	Tropospheric Chem. Modeling
Frank J. Murcray	University of Denver	Correlative Measurements; Spectroscopy
David M. Rider	JPL	Instrument Scientist; AES Team Leader
Curtis P. Rinsland	NASA Langley	Spectroscopy; Validation
Clive D. Rodgers	Oxford University	Retrieval Algorithms
Stanley P. Sander	JPL	Tropospheric Chemistry
Fredric W. Taylor	Oxford University	Strat-Trop Exchange
Helen M. Worden	JPL	Algorithm Team Leader, AES Analysis

Tropospheric Chemistry Hypothesis 1: Changes in tropospheric O_3 are a significant agent for climate change.

- through direct greenhouse forcing and indirect effects on CH_4 , aerosols, etc.

Harvard-GEOS Model: Ozone, ~500 hPa

Data Averaged for July 8



< 2.00e-08

> 8.00e-08

Ozone Volume Mixing Ratio

TES will measure vertical profiles of global tropospheric O_3 and other greenhouse gases. The data will be used to validate climate models.

JPL

Tropospheric Chemistry Hypothesis 2: Changes in tropospheric O_3 perturb the natural abundance of OH, the main atmospheric oxidant / cleanser, with wide ranging environmental consequences.

Harvard-GEOS Model: NO, ~200 hPa

Month: Jun Day: 1 Hr: 4 Lon/Lat Ranges: 105° - 175° / -30° - 30°



< 5.00000e-12

NO Volume Mixing Ratio

> 1.50000e-10

TES will measure most of the important IR-active species in the troposphere. O_3 formation/destruction cycles, from which the OH abundance may be inferred. TES will be able to resolve a detailed structure of O_3 abundance in the troposphere.

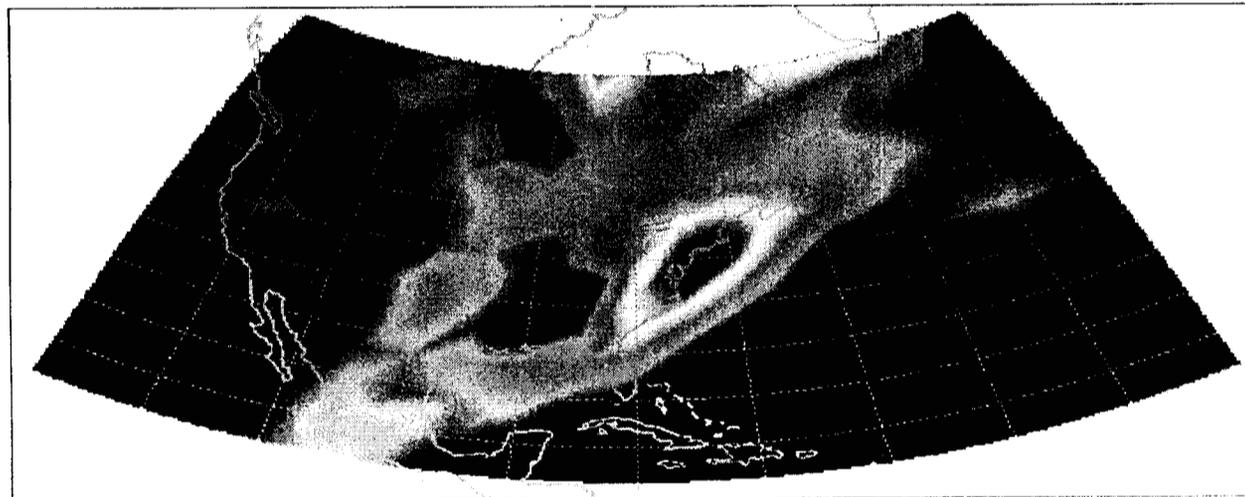
JPL

Tropospheric Chemistry Hypothesis 3: Increasing emissions of O_3 and aerosol precursors and CO will impact air quality worldwide.

- smog reduction by local emission controls could be offset by cumulative increases in global emissions.

Harvard-GEOS Model: CO, ~900 hPa

Data Averaged for 1 Day Start: Jan 9 End: Jan 9 Lon/Lat Ranges: -130° - -30° / 15° - 60°



< 8.00e-08

CO Volume Mixing Ratio

> 2.50e-07

component of atmospheric pollution that will allow U.S. to track continental outflows.

TES Limb and Nadir Observations

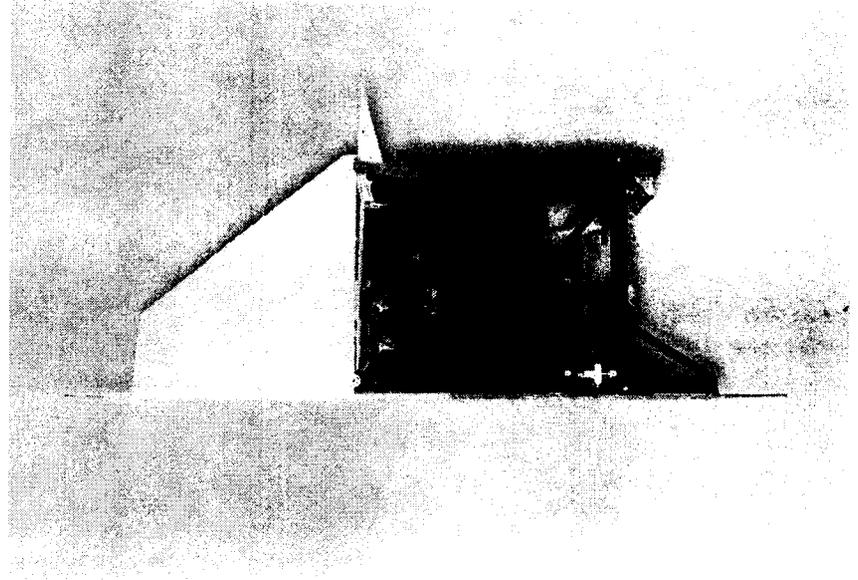
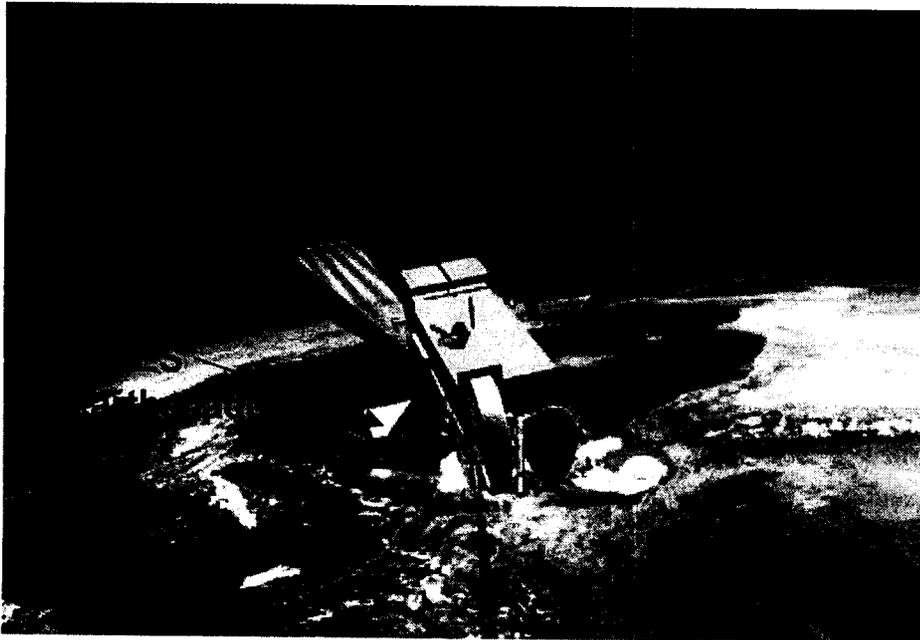
Limb Observations

Advantages

Good vertical resolution.
Enhanced sensitivity for trace constituents.

Disadvantages

Higher probability of cloud interference.
Poorer line-of-sight spatial resolution.



Nadir Observations

Advantages

Lower probability of cloud interference.
Excellent horizontal spatial resolution.

Disadvantages

Limited vertical resolution.

TES Standard Products & Required Sensitivity

Product Name	Product Source		Required Sensitivity*
	Nadir	Limb	
Level 1A Interferograms	✓	✓	
Level 1B Spectral Radiances	✓	✓	
Atmospheric Temperature Profile	✓	✓	0.5 K
Surface Skin Temperature	✓		0.5 K
Land Surface Emissivity [†]	✓		0.01
Ozone (O ₃) VMR Profile	✓	✓	1 - 20 ppbv
Water Vapor (H ₂ O) VMR Profile	✓	✓	1 - 200 ppmv
Carbon Monoxide (CO) VMR Profile	✓	✓	3 - 6 ppbv
Methane (CH ₄) VMR Profile	✓	✓	14 ppbv
Nitric Oxide (NO) VMR Profile		✓	40 - 80 pptv
Nitrogen Dioxide (NO ₂) VMR Profile		✓	15 - 25 pptv
Nitric Acid (HNO ₃) VMR Profile		✓	1 - 10 pptv
Nitrous Oxide (N ₂ O) VMR profile	✓	✓	Control [‡]

* Sensitivity range maps to expected concentration range.
NO_x measurements may need averaging to meet these requirements.

[†] Water (and, probably, snow & ice) emissivities are known and are therefore *input*, not output parameters

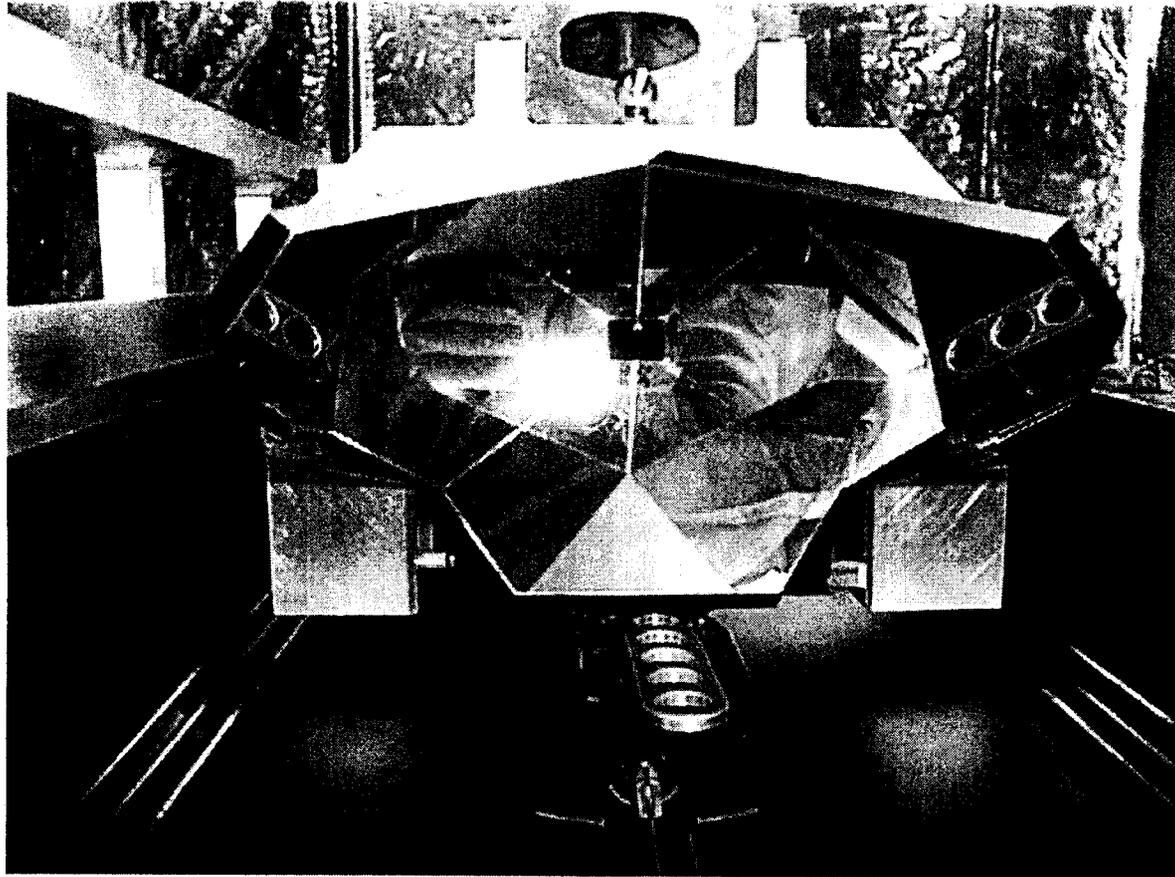
[‡] Tropospheric concentration known

Potential Special (Research) Products for TES

Chemical Group	Common Name	Formula	Product Source	
			Nadir	Limb
H _x O _y	Hydrogen Peroxide	H ₂ O ₂		✓
	Monodeuterated Water Vapor	HDO	✓	✓
	Ethane	C ₂ H ₆		✓
	Acetylene	C ₂ H ₂		✓
	Formic Acid	HCOOH	✓	✓
	Methyl Alcohol	CH ₃ OH	✓	✓
	Peroxyacetyl Nitrate	CH ₃ C(O)OONO ₂		✓
C-compounds	Acetone	CH ₃ C(O)CH ₃		✓
	Ethylene	C ₂ H ₄		✓
	Peroxynitric Acid	HO ₂ NO ₂		✓
	Ammonia	NH ₃	✓ *	✓
	Hydrogen Cyanide	HCN		✓
N-compounds	Dinitrogen Pentoxide	N ₂ O ₅		✓
	Hydrogen Chloride	HCl	✓ *	
	Chlorine Nitrate	ClONO ₂		✓
	Carbon Tetrachloride	CCl ₄		✓
Halogen compounds	CFC-11	CCl ₃ F	✓	✓
	CFC-12	CCl ₂ F ₂	✓	✓
	HCFC-21	CHCl ₂ F		✓
	HCFC-22	CHClF ₂		✓
	Sulfur Dioxide	SO ₂	✓	✓
	Carbonyl Sulfide	OCS	✓	✓
S-compounds	Hydrogen Sulfide	H ₂ S	✓ *	✓
	Sulfur Hexafluoride	SF ₆		✓

* Volcanic/industrial/biomass burning plume column densities only

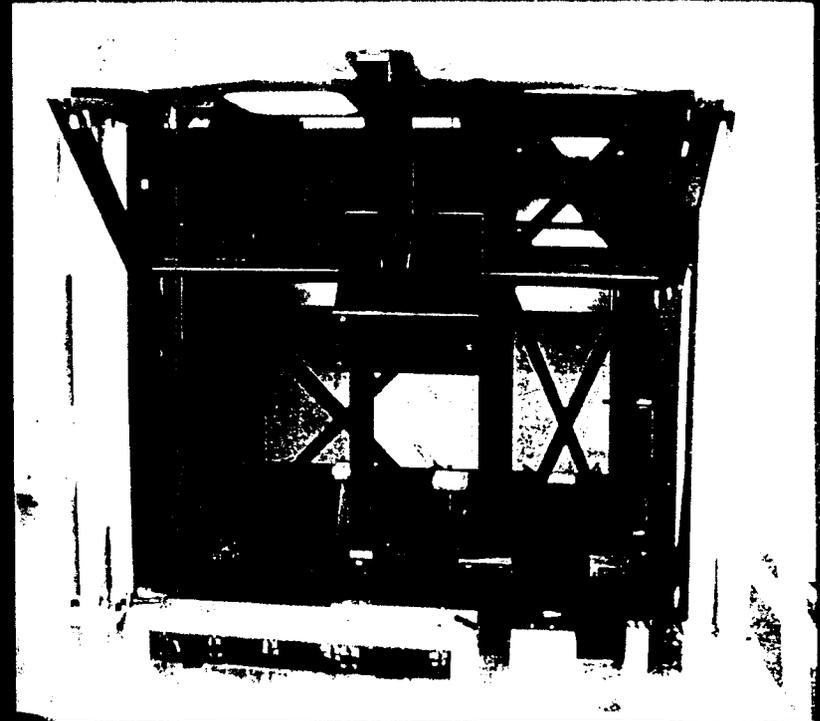
TES Instrument Specifications



View of the TES engineering model interferometer retroreflector

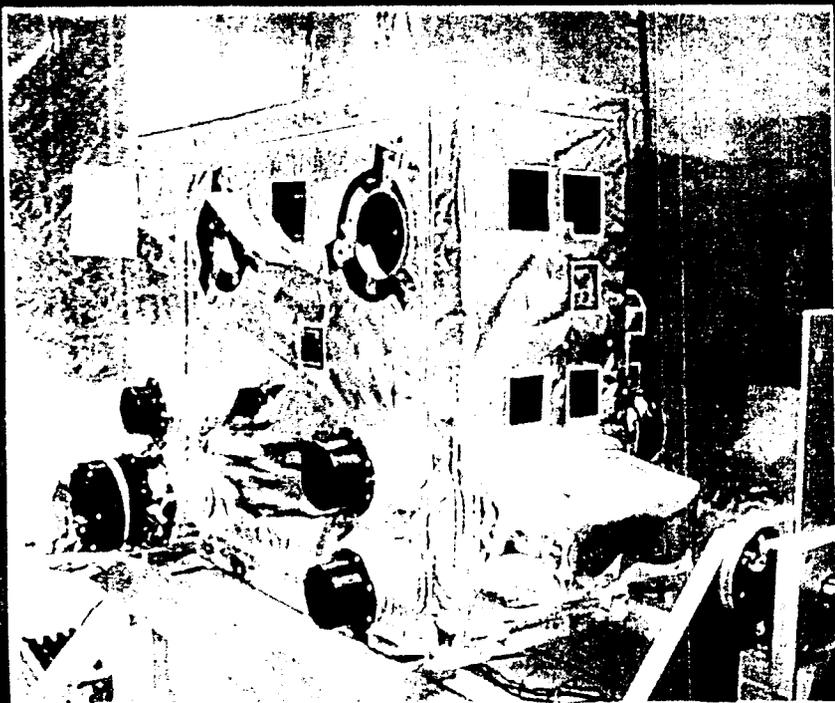
TES Allocations

Mass	385 kg
Average Power	334 W
Peak Power	361 W
Avg. Data Rate	4.5 Mbps
Peak Data Rate	6.2 Mbps
Actual Size	1.0 x 1.3 x 1.4 m (with earth shade stowed)
Lifetime	5 years on orbit



TES Structural Housing

TES Interferometer and Detectors



View of the TES engineering model interferometer with thermal blanket

Spectrometer Type	Connes'-type 4-port Fourier Transform Spectrometer
Max. Optical Path Difference	± 8.45 cm (nadir & calibration) ± 33.8 cm (limb); interchangeable
Scan (integration) Time	4 sec (nadir & calibration) 16 sec (limb)
Interferogram Sampling Metrology	Nd:YAG laser
Spectral Resolution (unapodized)	0.06 cm^{-1} (nadir) 0.015 cm^{-1} (limb)
Spectral Coverage	650 to 3050 cm^{-1} (3.2 to 15.4 μm)
Detector Arrays	4 (1 x 16) arrays, optically- conjugated, all MCT PV @65K
Signal-to-Noise Ratio (spectral)	Up to 600:1 Minimum requirement is 30:1

TES Pointing and Calibration

Field of Regard 45° cone about nadir;
trailing limb or cold space;
internal calibration sources

Pointing Accuracy 75 μ rad pitch
750 μ rad yaw
1100 μ rad roll

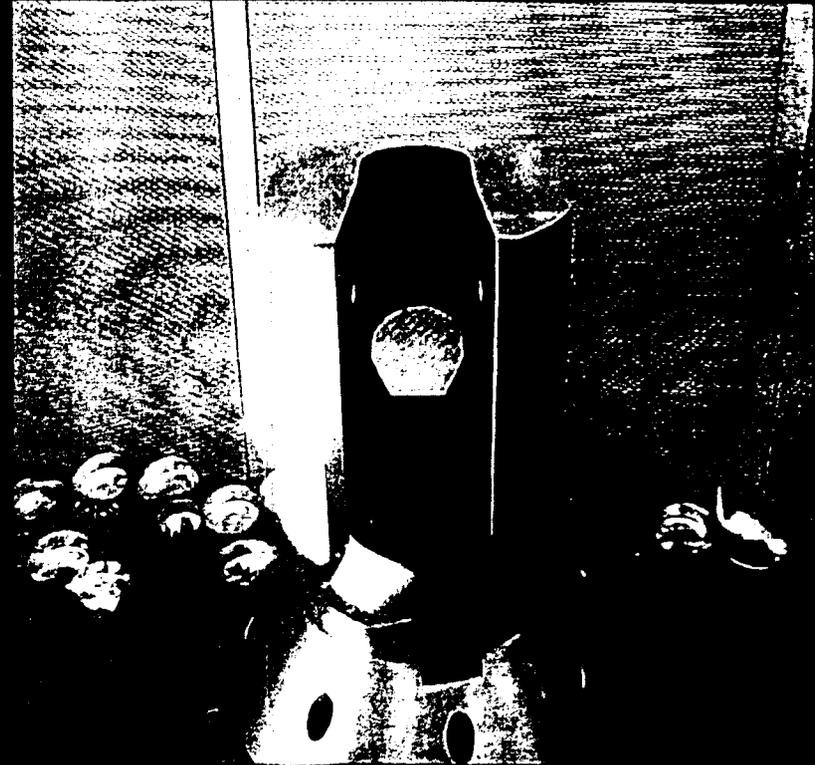
**Maximum Stare Time,
Nadir** 208 sec (40 nadir scans)

Spatial Resolution 0.5 x 5 km (nadir)
2.3 x 23 km (limb)

**Radiometric
Calibration** Internal, adjustable, cavity
blackbody (340K)
+ cold space view

Radiometric Accuracy = 1K 650 – 2500 cm^{-1}
= 2K 2500 – 3050 cm^{-1}

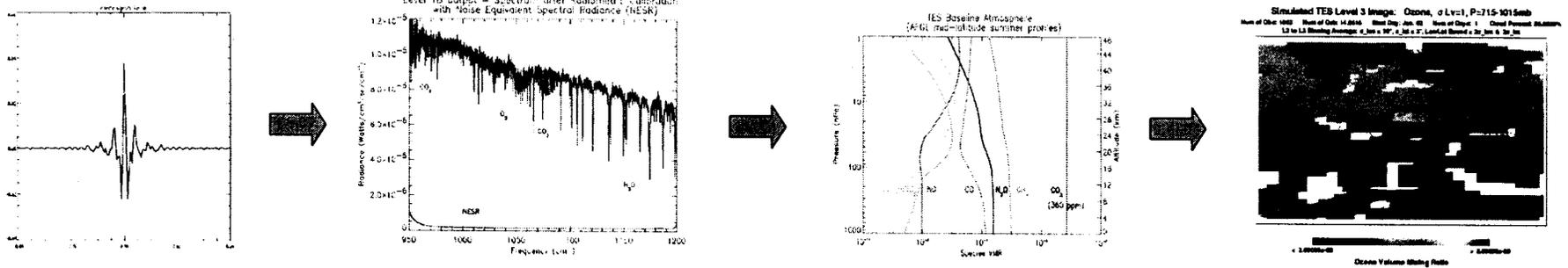
**Detector Array Co-
alignment Calibration** Internal thin slit source



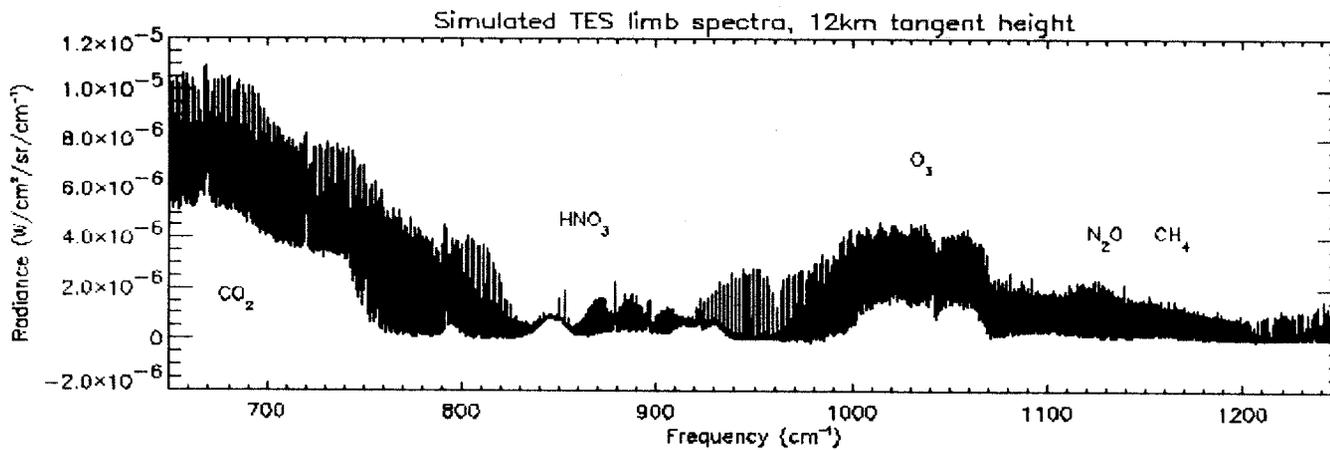
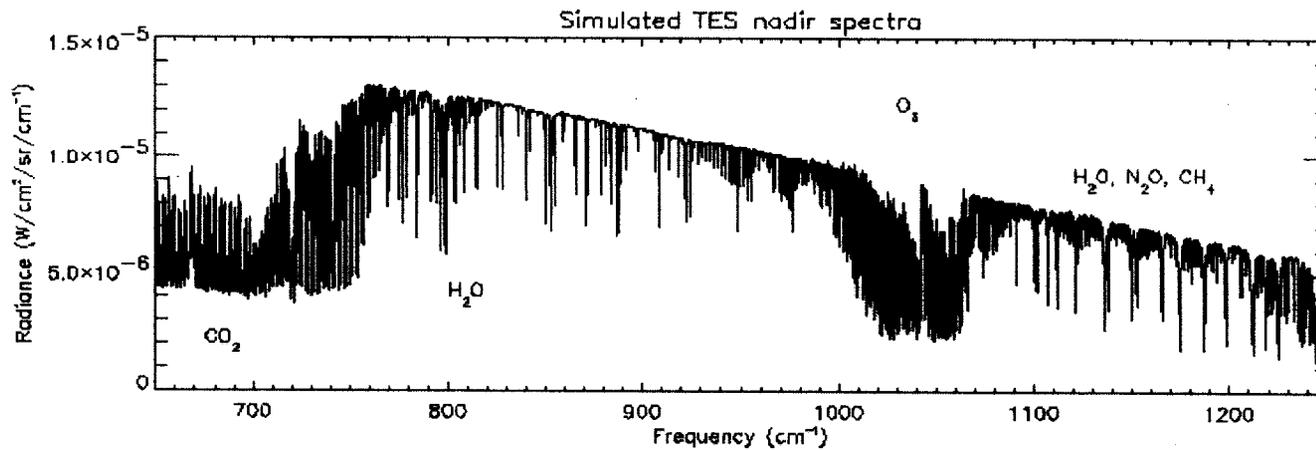
TES gimbal pointing mirror

TES Algorithm Overview

- Level 1A: Produces geolocated interferograms.
- Level 1B: Produces radiometrically and frequency calibrated spectra with NESR.
- Level 2: Produces VMR and temperature profiles.
- Level 3: Produces global maps.

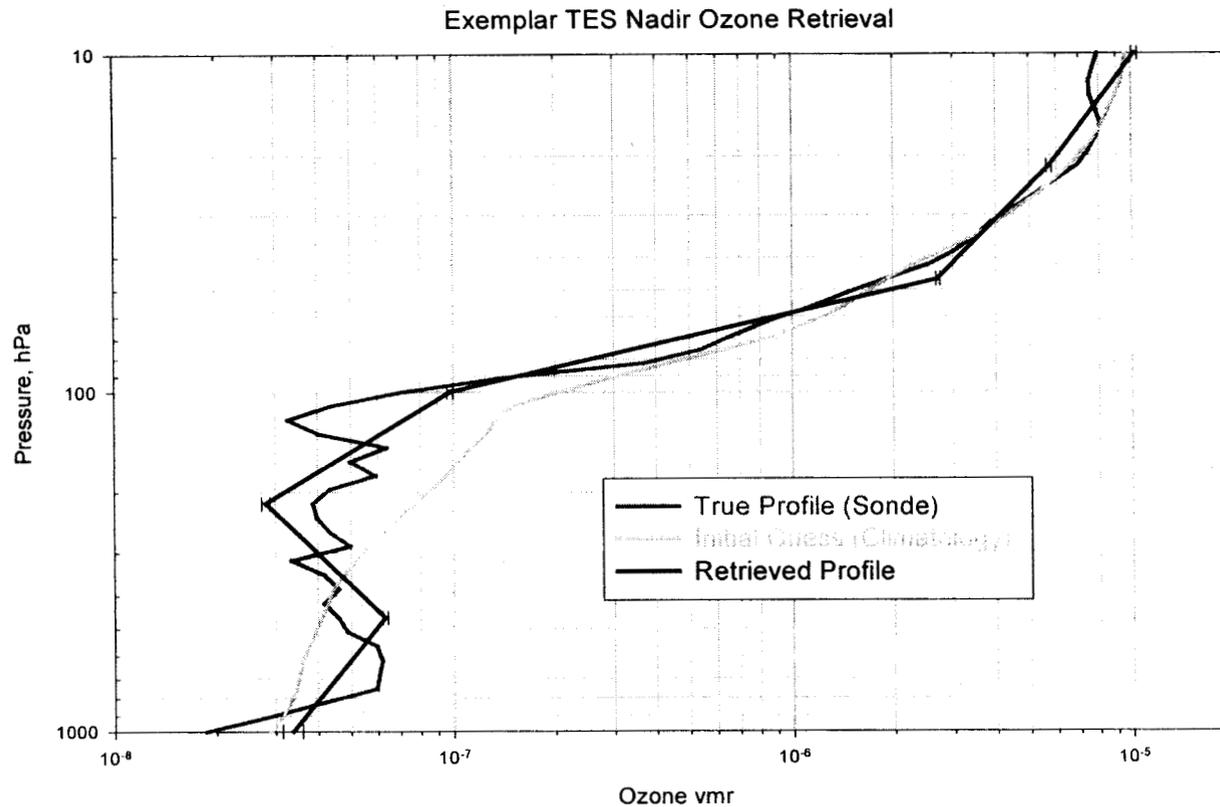


Level 1B Products



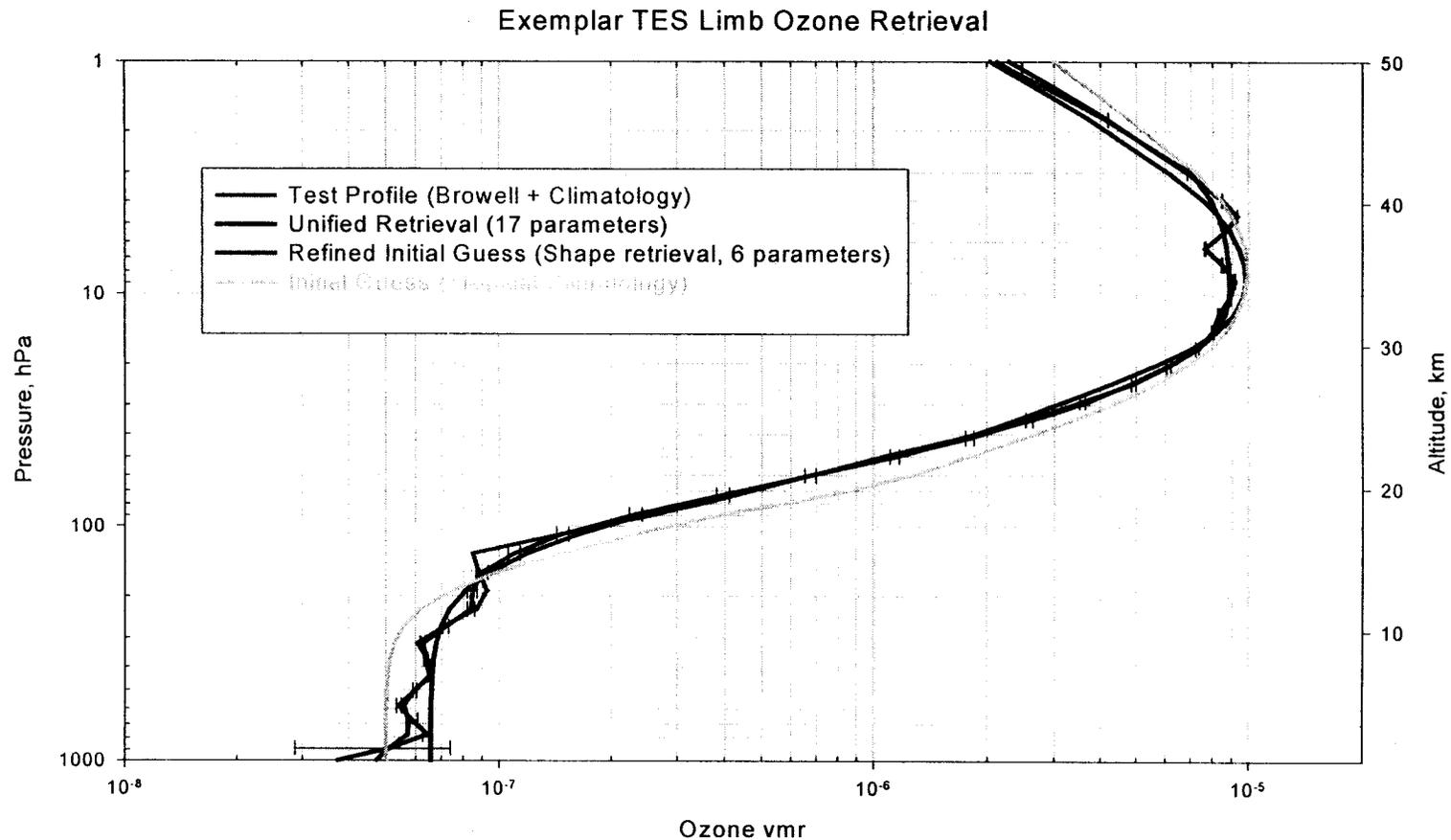
Level 2 Products

TES Nadir O3 retrievals will typically have 3 layers in the troposphere.



Level 2 Products

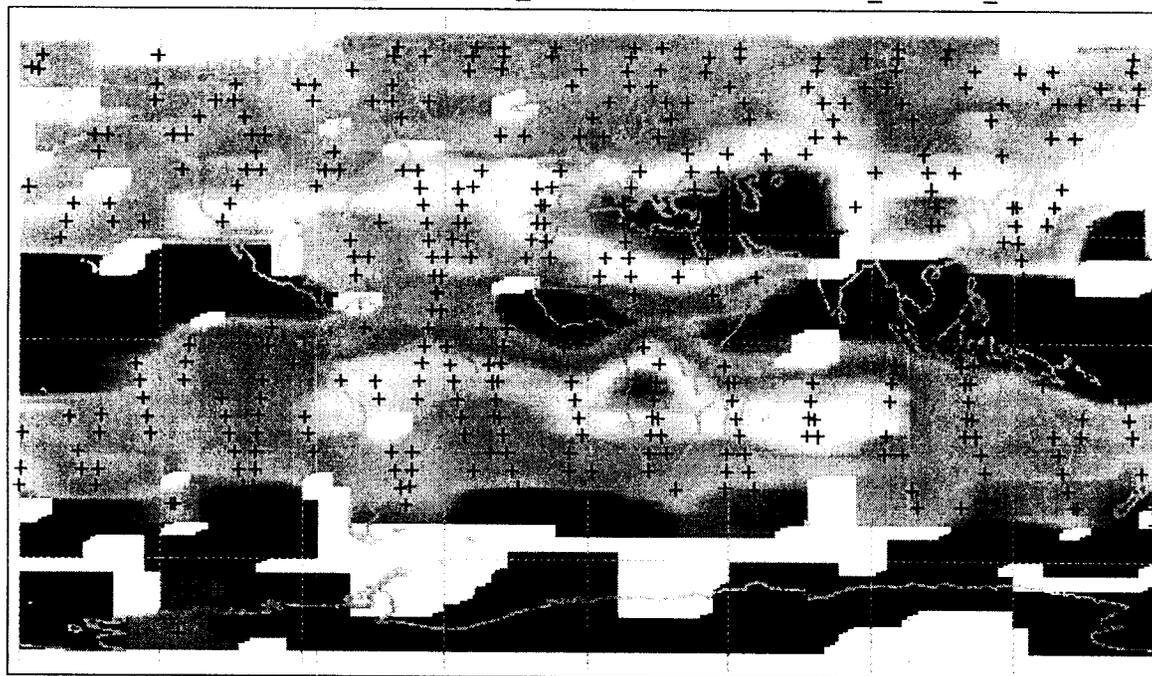
TES Limb O3 retrievals may have as many as 7 layers in the troposphere.



Level 3 Products

Simulated TES Level 3 Image: Ozone, P = 464.2 hPa

Num of Obs: 476/1063 Num of Orb: 14.56 Start Day: Aug. 15 Num of Days: 1 Total Cloud Percent: 55.2%
L2 to L3 Bin Ave: $\sigma_{lon} = 10.0^\circ$, $\sigma_{lat} = 3.0^\circ$, Lon/Lat Bound = $2\sigma_{lon}$ & $2\sigma_{lat}$



< 2.00e-08 > 7.50e-08

Ozone Volume Mixing Ratio

SUMMARY

TES will provide unprecedented information about the state of the Earth's lower atmosphere.

The capability of viewing the troposphere in both limb and nadir has never before existed for an infrared spectrometer.

Furthermore, the spectral coverage and resolution available will permit the search for trace gases which may be indicative of unforeseen atmospheric processes.